UNITED STATES PATENT APPLICATION

FOR

METHODS OF DEBONDING A COMPOSITE TOOLING

by

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I. CROSS-REFERENCE TO RELATED APPLICATION

[001] This application claims the benefit of U.S. Provisional Application No. 60/396,748, filed July 19, 2002, by Curtis Longo and Paul Teufel and titled METHODS OF DEBONDING A COMPOSITE TOOLING, the disclosure of which is expressly incorporated herein by reference.

II. BACKGROUND

A. Technical Field

[002] The present invention relates to methods of debonding a composite tooling. In particular, the present invention relates to methods of debonding a tooling for a fuselage.

B. Description of Related Art

[003] Presently, composite materials (such as fiber reinforced plastics) are increasingly being used to manufacture aircraft. The manufacture of such aircraft includes the manufacture of the fuselage (the central body of the aircraft), the internal frames of the fuselage, and the various other components of the aircraft. Often the manufacture of the internal frames of an aircraft fuselage with composites includes the use of trapped tooling to form the shape of the internal frames. For example, in some manufacturing processes, laminate fibers are wrapped around tooling to form the shape of the internal frames.

[004] Following formation of the fuselage, this tooling may need to be removed. Typically, the laminate part will have bonded to the tooling, making removal of the tooling difficult. Currently, soapy water is used to aid in the removal of the tooling. However, the soapy water does not affect the bond

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between the laminate and the tooling. Further, the soapy water leaves a residue on the laminate.

[005] A method of debonding a tooling for a fuselage that leaves little residue and releases the bond between the tooling and the fuselage would therefore provide many advantages. Therefore, it is desirable to provide a method of debonding a tooling from a fuselage that leaves little residue.

III. SUMMARY OF THE INVENTION

[006] Apparatus and methods consistent with the invention may provide for a method of removing a mandrel from a part. The method includes creating a vacuum in the mandrel, applying a debonding agent on the surface of the mandrel, and removing the mandrel from the part.

[007] Additional aspects of the invention are disclosed and defined by the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

IV. BRIEF DESCRIPTION OF THE DRAWINGS

[008] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments consistent with the invention and, together with the following description, serve to explain the principles of the invention.

[009] In the drawings:

[010] Figure 1 is a perspective view of a fuselage for an aircraft;

[011] Figure 2 is a block diagram illustrating apparatus for manufacturing a fuselage;

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[012] Figure 3 is a flow diagram illustrating a process for creating an internal frame of a fuselage using a mandrel, as shown in Figure 2;

[013] Figure 4 illustrates a mandrel for an internal frame, as described in Figure 3;

[014] Figure 5 illustrates formation of a mandrel, as shown in Figure 4;

[015] Figure 6 illustrates frame mandrel placement on a fuselage tooling, as shown in Figure 5;

[016] Figure 7A is a perspective view of a fuselage formed on tooling, as shown in Figure 6;

[017] Figure 7B is a cut-away view of fuselage formed on tooling, as shown in Figure 7A;

[018] Figure 8 is a flow diagram illustrating a process for removing an internal frame mandrel of the fuselage consistent with one embodiment of the present invention, as shown in Figure 7;

[019] Figure 9 illustrates cutting an opening in a fuselage consistent with one embodiment of the present invention, as shown in Figure 8;

[020] Figure 10 illustrates applying a vacuum cycle on a frame mandrel consistent with one embodiment of the present invention, as shown in Figure 9;

[021] Figure 11 illustrates applying a debonding agent on a frame mandrel consistent with one embodiment of the present invention, as shown in Figure 10; and

[022] Figure 12 illustrates removing a frame mandrel consistent with one embodiment of the invention, as shown in Figure 11.

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V. DESCRIPTION OF THE EMBODIMENTS

A. Introduction

[023] Figures 1-7 illustrate a process for creating a fuselage using tooling. This process is only exemplary and is described for the purpose of providing background for the present invention. Other processes for creating a fuselage using tooling may also be used. Figures 8-12 describe methods of debonding tooling for a fuselage consistent with the present invention.

[024] Figure 1 is a perspective view of a fuselage for an aircraft. As shown in Figure 1, a fuselage 100 comprises an exterior skin 140, frame sections 120, and attachment pockets 160 for wings. Fuselage 100 may also comprise other frame sections, attachments pockets, and flanges (not shown). Fuselage 100 may also comprise other components and subcomponents (not shown).

[025] Figure 2 is a block diagram illustrating apparatus for manufacturing a fuselage. As shown in Figure 2, the apparatus for manufacturing a fuselage 200 include tooling 220 and other 240. Tooling 220 includes any tooling apparatus for manufacturing a fuselage. For example, tooling 220 may include metal molds, molds made from composite materials, and/or mandrels made from metals and composite materials. Tooling 220 also includes toolings made from elastomeric materials such as silicone, urethane, or natural rubbers. Tooling 220 further includes plastic or metal dies and punches. Other 240 may include molding apparatus, integrated tooling and molding apparatus, and filament winding apparatus, as well as any other apparatus.

[026] In one implementation, tooling 220 includes an elastomeric tooling for an internal frame mandrel. In this implementation, the elastomeric tooling is a

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mandrel filled with media, which is used to maintain the internal shape of a frame during construction of the fuselage. This implementation is merely exemplary, and other implementations may also be used.

[027] Figure 3 is a flow diagram illustrating a process for creating an internal frame of a fuselage using a mandrel, as shown in Figure 2. As shown in Figure 3, in one implementation, process 300 for creating an internal frame of a fuselage using a mandrel comprises prepare mandrel 310, form mandrel 320, place mandrel 330, form part 340, remove mandrel 350, and reuse 360. As described above, this process is only exemplary and is described for the purpose of providing background for the present invention. Other processes for creating a fuselage using tooling may also be used consistent with the invention.

[028] In this implementation, process 300 begins with prepare mandrel 310. In this implementation, prepare mandrel 310 comprises the selection of the size, shape, and type of mandrel to form the internal frame of the fuselage. Prepare mandrel 310 is further described in Figure 4.

[029] In this implementation, prepare mandrel 310 is followed by form mandrel 320. Form mandrel 320 comprises the forming of the mandrel to the desired shape of the internal frame. Form mandrel 320 may also comprise filling the mandrel with media. Form mandrel 320 is further described in Figure 5.

[030] In this implementation, form mandrel 320 is followed by place mandrel 330. Place mandrel 330 comprises the placement of the frame mandrel onto a tooling for formation of the internal frame of the fuselage. Place mandrel 330 is further described in Figure 6.

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[031] In this implementation, place mandrel 330 is followed by form part 340. Form part 340 comprises the formation of the fuselage by any process using a frame mandrel. This may comprise the winding of filament around the mandrel. Form part 340 is further illustrated in Figures 7A-7B.

[032] In this implementation, form part 340 is followed by remove mandrel 350. Remove mandrel 350 comprises the removal of the mandrel from the fuselage consistent with one embodiment of the present invention. Remove mandrel 350 may also comprise the extraction of media from the mandrel. Remove mandrel 350 is further described in Figures 8-12.

[033] In this implementation, remove mandrel 350 is followed by reuse 360. As shown in Figure 3, after remove mandrel 350, reuse 360 indicates that the mandrel may be reused again.

[034] The stages in Figure 3 are merely exemplary, and other stages and other implementations may also be used.

[035] Figure 4 illustrates a mandrel for an internal frame, as described in Figure 3. Figure 4 shows an internal frame mandrel 400, such as, for example, a reusable elastomeric mandrel currently available through International Design Technologies, Inc (IDT). This implementation is merely exemplary, and other implementations may also be used.

[036] Mandrel 400 may comprise premolded silicone or any other appropriate form or substance. Some silicone materials that have been found acceptable include those available from Mosite, Kirkhill, and D Aircraft Products. In addition, there are many other suppliers of high temperature (up to 400°F),

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unfilled, and uncured silicone sheet materials that may be used, depending upon the cure temperature of the desired part. In one implementation, a material, such as Depco 63 available from D Aircraft Products, can be sprayed to make an elastomeric mandrel. These implementations are merely exemplary, and other implementations may also be used.

[037] Figure 5 illustrates formation of a mandrel, as shown in Figure 4. As shown in Figure 5, mandrel 520 is placed in a form tool 510 to form the desired shape of the internal frame mandrel. In one implementation, mandrel 520 is filled with air to force mandrel 520 to conform to the shape of form tool 510. This implementation is merely exemplary, and other implementations may also be used.

[038] In another implementation, media (not shown), such as ceramic spheres, may be placed inside mandrel 520 to form the desired shape of mandrel 520. In one implementation, mandrel 520 is vibrated to allow for more complete filling of the mandrel with media. These implementations are merely exemplary, and other implementations may also be used.

[039] Figure 6 illustrates frame mandrel placement on a fuselage tooling, as shown in Figure 5. As shown in Figure 6, frame mandrel 650 is placed around fuselage tooling 600. Frame mandrel 650 forms the internal frame structure of the fuselage to be formed around fuselage tooling 600. In one implementation, fuselage tooling 600 may have recesses in which frame mandrel 650 is placed. This implementation is merely exemplary, and other implementations may also be used.

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[040] Figure 7A is a perspective view of a fuselage formed on tooling, as shown in Figure 6. As shown in Figure 7A, fuselage 700 has been constructed around fuselage tooling 600 and frame mandrel 650 (not shown here, but described in Figure 6). In one implementation, fuselage 700 comprises an outer skin 710. Other methods may be used to form outer skin 710. In one implementation, composite filament is wound around fuselage tooling 600 to form outer skin 710. This implementation is merely exemplary, and other implementations may also be used.

[041] Figure 7B is a cut-away view of fuselage formed on tooling, as shown in Figure 7A. As shown in Figure 7B, outer skin 710 has been placed around frame mandrel 650 and fuselage tooling 600.

[042] In this implementation, fuselage tooling 600 comprises an armature 770 and a bag 750 placed around armature 770. Bag 750 has been filled with media 740 to hold bag 750 to a desired shape. The shape of bag 750 forms the overall shape of the part to be constructed (i.e., a fuselage).

[043] In this implementation, an inner skin 720 has been placed directly on bag 750. Inner skin 720 may be constructed of any appropriate filament material. Frame mandrel 650 has been placed on top of inner skin 720. As shown in Figure 7B, in this implementation, frame mandrel 650 has been filled with media 790, as described in Figure 5.

[044] In this implementation, core 730 and filler block 760 have been placed on top of inner skin 720. Core 730 provides stiffness for the fuselage. Filler block 760 is used to assist in winding outer skin 710.

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[045] Outer skin 710 is cured around core 730, filler block 760, and frame mandrel 650 to form the fuselage. During this process, frame mandrel 650 may become bonded to inner skin 720 and/or outer skin 710. Therefore, in order to remove frame mandrel 650, it would be desirable to release these bonds. Figures 8-12 will describe a method of debonding frame mandrel 650 from inner skin 720 and/or outer skin 710.

B. Methods of the Invention

[046] Figure 8 is a flow diagram illustrating a process for removing an internal frame mandrel of the fuselage consistent with one embodiment of the present invention, as shown in Figure 7. As shown in Figure 8, in one implementation, process 800 for removing an internal frame mandrel of a fuselage comprises cut opening 810, vacuum cycle 820, apply debonding agent 830, stand 840, and remove mandrel 850.

[047] In this implementation, process 800 begins with cut opening 810. In this implementation, cut opening 810 comprises the cutting of an opening in the extraction end of the fuselage to allow for removal of the mandrel. Cut opening 810 may also include the removal of media from the mandrel following the cutting of the opening. Cut opening 810 is further described in Figure 9. In another implementation, the fuselage may be designed to include an opening for removal of the mandrel. In this implementation, cut opening 810 would not be performed. These implementations are merely exemplary, and other implementations may also be used.

[048] In this implementation, cut opening 810 is followed by vacuum cycle 820. Vacuum cycle 820 comprises cycling application of a vacuum on the

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mandrel to break the cohesive bond between the mandrel and the fuselage. Vacuum cycle 820 is further described in Figure 10.

[049] In this implementation, vacuum cycle 820 is followed by apply debonding agent 830. Apply debonding agent 830 comprises the application of a debonding agent on the mandrel. Apply debonding agent 830 is further described in Figure 11. In one implementation, apply debonding agent 830 is performed simultaneously with vacuum cycle 820. This implementation may provide for better distribution of the debonding agent onto the mandrel.

[050] In this implementation, apply debonding agent 830 is followed by stand 840. Stand 840 comprises allowing the debonding agent to stand on the mandrel and remove the cohesive bond between the mandrel and the fuselage. Stand 840 is further illustrated in Figure 11.

[051] In this implementation, stand 840 is followed by remove mandrel 850. Remove mandrel 850 comprises the removal of the mandrel from the fuselage. Remove mandrel 850 is further described in Figure 12.

[052] The stages in Figure 8 are merely exemplary, and other stages and other implementations may also be used.

[053] Figure 9 illustrates cutting an opening in a fuselage consistent with one embodiment of the present invention, as shown in Figure 8. As shown in Figure 9, following creation of the fuselage, as described in Figures 7A-7B, fuselage 900 comprises internal frame 920, which was formed around internal frame mandrel 910. Internal frame 920 has been cut to reveal a portion of internal frame mandrel 910. In one implementation, the location of the cut is

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chosen to allow for the straightest path to remove internal frame mandrel 910. At this point, if frame mandrel 910 contains media, this media may be removed. These implementations are merely exemplary, and other implementations may also be used.

[054] Figure 10 illustrates applying a vacuum cycle on a frame mandrel consistent with one embodiment of the present invention, as shown in Figure 9. As shown in Figure 10, fuselage 1000 comprises internal frame 920, which has been cut-away to reveal a portion of frame mandrel 910.

[055] As shown in Figure 10, a vacuum source 1010 is connected to vacuum hose 1020, which is inserted into frame mandrel 910. A vacuum is created in mandrel 910 by vacuum source 1010. In one implementation, a vacuum is alternately created in mandrel 910 and then released several times. In another implementation, the vacuum is held for 5-10 seconds and is alternately created and released 2-3 times. The application of a vacuum cycle to mandrel 910 will cause mandrel 910 to contract. This contraction will break some of the cohesive bonds between mandrel 910 and internal frame 920. These implementations are merely exemplary, and other implementations may also be used.

[056] Figure 11 illustrates applying a debonding agent on a frame mandrel consistent with one embodiment of the present invention, as shown in Figure 10. As shown in Figure 11, a debonding agent 1100, such as isopropyl alcohol, is applied in areas between frame mandrel 910 and internal frame 920.

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In one implementation, debonding agent 1100 is applied as far into the openings between frame mandrel 910 and internal frame 920 as possible.

[057] The amount of debonding agent 1100 to apply may vary based on the size of frame mandrel 910. In this implementation, debonding agent 1100 may be applied using a long tipped squirt bottle or wand tip. Vacuum hose 1020 is also visible in this figure. In another implementation, debonding agent 1100 is applied during the application of the vacuum cycle described in Figure 10. These implementations are merely exemplary, and other implementations may also be used.

[058] After application of debonding agent 1100, it is allowed to stand for a specified period of time. During the stand time, debonding agent 1100 will wet the surface of the mandrel by capillary action and attack the cohesive bond between mandrel 910 and internal frame 920. In one implementation, debonding agent 1100 dissolves the epoxy film between mandrel 910 and internal frame 920. This will allow mandrel 910 to be more easily removed from internal frame 920. This implementation is merely exemplary, and other implementations may also be used.

[059] In one implementation, isopropyl alcohol is used as debonding agent 1100. In this implementation, approximately 2-3 oz. is applied and allowed to stand for approximately three to five minutes. The amount of isopropyl alcohol to apply and the stand time may vary based on the size of mandrel 910. In addition to removing the bond between mandrel 910 and internal frame 920, alcohol also will not adversely affect the fuselage and it evaporates quickly so

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that little residue will be left. This implementation is merely exemplary, and other materials and stand time may be used.

[060] Figure 12 illustrates removing a frame mandrel consistent with one embodiment of the invention, as shown in Figure 11. As shown in Figure 12, following application of the debonding agent, mandrel 910 is removed from frame 920. Mandrel 910 may be removed either manually or by using an apparatus. In one implementation, mandrel 910 is removed by hand using a pulling motion. Following removal of mandrel 910, mandrel 910 may be cleaned and reused in the formation of another fuselage. In one implementation, the opening in frame 920 may be repaired using a pre-cured repair patch. These implementations are merely exemplary, and other implementations may also be used.

VI. CONCLUSION

[061] As described above, therefore, other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims and their equivalents. In this context, equivalents mean each and every implementation for carrying out the functions recited in the claims, even if not explicitly described therein.

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